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(54) IMPROVEMENTS IN OR RELATING TO SOURCES OF X-RADIATION

(71) We, EMI LIMITED, a British company of Blyth Road, Hayes, Middlesex, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to sources of X-radiation and is especially, though not exclusively, related to X-ray sources for use with radiological diagnostic apparatus.

In British Patent No. 1,475,303 there is described an apparatus for examining a body which requires a beam of radiation having a wide angular spread emanating from a relatively small source. The shape of the required beam of radiation, in plan, can be considered to resemble that of a fan having only a small thickness measured in a direction perpendicular to its planar surfaces.

A suitable source for producing such a fan-like sheet of X-radiation is described in British Patent No. 1,497,396. This source, which is indicated in Figure 1 of the accompanying drawings emits radiation over a wide spread of directions from which the required beam is defined by a suitable aperture. However an X-ray source such as that shown in Figure 1 produces a beam which is not uniform over its entire spread. The examining apparatus referred to above can use such a beam but suitable adjustments and corrections must be made, in the form of additional computation, thereby introducing additional complications into the apparatus.

It is an object of this invention to provide an alternative source of a fan-like beam of radiation having improved uniformity to substantially prevent or reduce said complication.

According to the invention there is provided an x-ray generating tube for generating a substantially planar fan of substantially uniformly energetic x-radiation, the tube including a source of a beam of electrons, a target member arranged to emit x-radiation when bombarded by the electrons in the beam, and means for constraining said beam to impinge upon said target member and for causing the electrons of said beam to converge in the vicinity of said target member; said target member being formed with a curved surface exposed to said electron beam the electron paths over the beam cross-section being incident on the target surface at substantially equal angles, the curvature of said surface occurring in the plane of said fan of radiation, and means being provided for selecting said fan from the radiation emitted by said target member, so that the mean direction of travel of the radiation within the fan is substantially sideways to the general path of said beam of electrons.

Embodiments of the invention will now be described with reference to the accompanying drawings in which:—

Figure 1 shows the source of X- radiation mentioned above as already described,

Figure 2 shows a source of X-radiation incorporating the invention, and

Figure 3 shows a detail of an alternative form of Figure 2.

The previously proposed source for a fan-like beam of X-rays is shown in Figure 1, from which many known features necessary to an X-ray source have been omitted for the sake of clarity. The source includes an anode and a cathode enclosed in an evacuated envelope and forms an X-ray tube. Electrons, whose paths are shown by the broken lines 1, are emitted from a cathode 2. They stream across to a tungsten target 3 which is inset in an anode member 4 of copper and which can be maintained at a suitable positive potential relative to the cathode. These electrons travel along the axis between the cathode and anode and are focussed as required by means which are not shown. X-radiation is emitted from the target over a wide range of angles and some

X-rays pass through window 5 in anode member 4. Window 5 is formed from a suitable conducting material so that its presence does not deform the electrostatic field required to be defined by the anode member 4. Of the X-rays passing through the window a further restricted quantity, indicated by reference numeral 6, pass through a slot 7, in a section of the tube wall 8 by means of another suitable window 9. The tube wall as indicated at 8 would normally be a specially provided section having sufficient thickness to give the required collimation. The slot 7 is arranged to define the required fan of radiation which, in Figure 1, extends in a plane normal to the plane of the drawing.

X-rays are known to be emitted predominantly normally to the path of the incident electrons for low electron energies but for energies of 100 KeV they are emitted at about 50° to the path in the forward direction. However a significant amount of emission is still found along the normal. It will therefore be apparent that the emitted X-rays will substantially form a torus around the incident electron beam having a general alignment inclined to the axis in dependence on the electron energy. The X-rays will therefore have a variation of intensity and quality over the slice of the torus including the desired fan and therefore over the spread of the fan.

The X-rays source embodying the invention, shown schematically in Figures 2 and 3, differs primarily from that described with reference to Figure 1 in the form of the target. The flat tungsten target 3 is replaced with a tungsten target 10 which in a preferred form is cylindrical or spherical. The target is similarly inset into the anode member 4. A beam of electrons whose general path is indicated at 11 is produced by an electron gun 12. The beam need not be circularly symmetrical but can be flat, in the plane of the drawing. The electrons from gun 12 are caused to converge onto the anode. This convergence can be caused in various ways. For example an electron gun can be arranged to produce a beam in which electrons are caused to converge some distance from the gun by an electrostatic focussing system. (See Ehrenberg and Spear, Proc. Phy. Soc. B, 64, p67, 1951.) Such a gun 12 has a filament F exposed in an aperture in a cathode shield C within a grid cylinder G and an electrode E with which the grid is coaxial. Grid G and electrode E are maintained at or near the same potential in operation. Figure 2 shows a beam of electrons directed from the gun along the axis of the gun and target, i.e. normal to the target. The potential between the gun and anode is such that X-radiation is produced normally to the paths at which the electrons are incident on the target. The electrons are incident on the target at a range of angles to the axis and therefore the X-radiation is emitted along paths over a range of angles each substantially normal to the respective path of incidence. As explained above these paths are only an indication of the general alignment of a torus of rays. Accordingly the total radiation is the result of the merging of the radiation of the torii. Lines 13a and 13b indicate the limits between which the total intensity of radiation is substantially constant in the plane of the drawing. Window 5, of conducting material as before, is dimensioned to set these limits to the radiation fan passing out from the target in the plane of the paper. If required the thickness of the fan in the direction perpendicular to the plane of the paper can be controlled by suitable shaping of window 5.

It will be realised that, since the source should approximate as closely as possible to a point source of X-rays, the target 10 should be of sufficiently small dimensions to satisfy this requirement. Furthermore there is some crossing of the X-rays in the fan caused by the non-normal X-ray emission. It may therefore be necessary to provide a fan-like array of collimators, to ensure a fan of well-defined individual X-ray beams without crossing beams.

Further collimating means, not shown, are provided to restrict the spread of X-rays normal to the plane of the drawing, that is to define the thickness of the fan. This collimating means may be in addition to or instead of the control achieved by the use of the window as mentioned above.

It will also be apparent that, since the fan-like beam of X-rays is formed by merger of radiation resulting from the impact of electrons on the target at angles of incidence on the surface which can be made substantially the same, the intensity and character of the X-rays is significantly more uniform throughout the fan than for the source shown in Figure 1 in which the beam varies as described above.

As a further development the target can be arranged such that the electron beam is directed along a path at an angle to the axis between the gun and target to strike the curved target surface. Fig. 3 shows this arrangement with reference to the area of the target. A fun similar to that at 12 in Figure 2 is assumed but the electron beam is directed along a line other than the direct axis between the gun and the target. Such direction can be achieved by suitable shaping of the electrostatic fields between the gun and target. Clearly the gun and anode must be separated by a distance large enough to prevent breakdown under the potential difference between them. However the spacing must not be so great as

to reduce the convergence angle of the beam. Convergence angles of some 30° to 50° appear to be desirable to produce a fan beam for the diagnostic radiological use of the source. The converging beam 21 impinges on a part of the target 20 most of which is below the axis. It is assumed in this embodiment that the anode-gun potential difference is sufficient to produce X-radiation at angle forward of the normal to the path of an incident electron. The radiation 23 is again of fan form and its limits can be set by a window such as 5, (not shown) to produce a merged beam of uniform radiation intensity in the plane of the drawing.

The converging beam has a form determined by the fan of radiation required. The electrons of the beam converge, not to a focus at some point inside or outside the anode surface, but rather converge with substantial positive aberration, as indicated by the bracket B encompassing the intersections of the electron paths in the beam. Such an electron beam form can be obtained by passing the beam through an electrostatic lens so that all the beam passes through one half of the lens. Electron path 211 would then be the axial ray of the lens, path 215 the marginal ray and rays 212—214 the zonal rays, all of one half of the lens. Figure 3 shows the electron paths and X-radiation beam when each electron path is at substantially 30° to the anode surface at the point of incidence.

Clearly the angle to the axis at which the electron beam is directed may be varied to modify the form of the fan of radiation, for example when the value of anode-gun potential difference is changed. Also the shape of the surface of the target may be altered, by experiment if required, to control the angle at which particles are incident on the surface and X-rays are emitted to improve the already substantially uniform intensity in the fan of radiation. The combination of beam form and anode shape for a particular fan formation can thus be achieved. Other charged particles, such as protons may be used to bombard the target to produce X-radiation.

WHAT WE CLAIM IS:—

1. An x-ray generating tube for generating a substantially planar fan of substantially uniformly energetic x-radiation, the tube including a source of a beam of electrons, a target member arranged to emit x-radiation when bombarded by the electrons in the beam, and means for constraining said beam to impinge upon said target member and for causing the electrons of said beam to converge in the vicinity of said target member; said target member being formed with a curved surface exposed to said electron beam, the electron paths over the beam cross-section being incident on the target surface at substantially equal angles, the curvature of said surface occurring in the plane of said fan of radiation, and means being provided for selecting said fan from the radiation emitted by said target member, so that the mean direction of travel of the radiation within the fan is substantially sideways to the general path of said beam of electrons.

2. A tube according to Claim 1 wherein said means for constraining said beam to impinge on said target member and for causing the electrons of said beam to converge in the vicinity of said target member includes an electrostatic focussing system.

3. A tube according to Claim 2 in which said electrostatic focussing system provides positive spherical aberration to the convergence of the electrons.

4. A tube according to any preceding claim in which the general path followed by the electron beam extends along the axis between the source and the target.

5. A tube according to any of claims 1 to 3 in which the general path followed by the electron beam is inclined to the axis between the source and the target.

6. A tube according to any preceding claim in which said means for selecting said fan comprises a window in the target member.

7. An x-ray tube substantially as herein described with reference to Figure 2 or to Figure 3 of the accompanying drawings.

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2 SHEETS

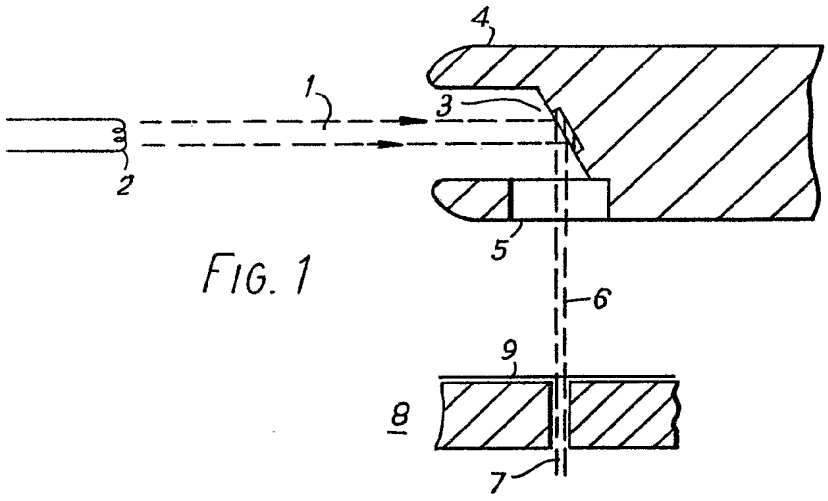


FIG. 1

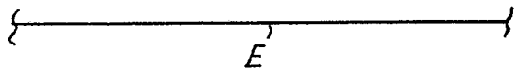
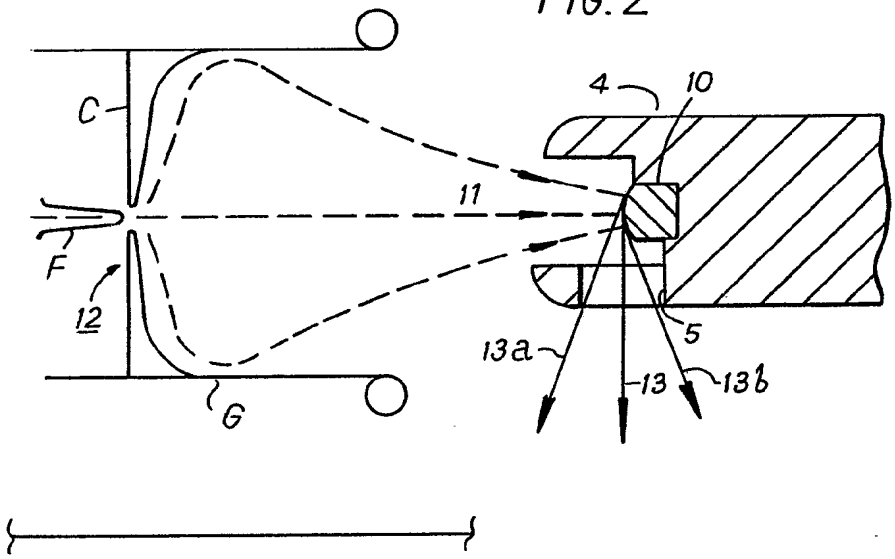


FIG. 2



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COMPLETE SPECIFICATION

SHEET 2

FIG. 3